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13. ABSTRACT *(Maximum 200 words)*

The goal of this funded research was to complete the development of a fault diagnosis system for rotating machinery, which was initiated under a previous AFOSR grant (F49620-95-1-0090). The focus of the proposed research was strongly linked to the accomplishments achieved to date. Because the value of such a system is ultimately gauged by it's applicability and utility in real world settings, a major component of the research results contained herein center on real world issues which violate many of the assumptions used to develop advanced a signal analysis methods. Specific technical outcomes related to this research include: (a) Characterization of the nature of "real-world" sinusoids associated with rotating machinery (b) Development of improved periodic time/frequency analysis tools for quasi-periodic processes (c) Implementation of theoretical statistics derived under previous funding in the development of a multi-resolution, intelligent methodology for estimating the spectral information associated with mixed random processes. We have also aggressively pursued establishment of research ties with U.S. and foreign industries and academic institutions to evaluate the utility of the above results and to guide the direction of future research and funding opportunities. These efforts are documented in this report. We believe that they are valuable not only for transitions of research results obtained under this grant, but also for securing future support from other agencies.

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PROJECT TITLE: Stochastic characterizations for signals and systems associated with quasi-periodic systems
AFOSR Grant Number: F49620-98-1-0252
Grant Start Date: 1 February 1998
Principal Investigator: Peter J. Sherman

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SECTION A

EXECUTIVE SUMMARY

The goal of this funded research was to complete the development of a fault diagnosis system for rotating machinery, which was initiated under a previous AFOSR grant (F49620-95-1-0090). The focus of the proposed research was strongly linked to the accomplishments achieved to date. Because the value of such a system is ultimately gauged by it's applicability and utility in real world settings, a major component of the research results contained herein center on real world issues which violate many of the assumptions used to develop advanced signal analysis methods. Specific technical outcomes related to this research include:

(a) Characterization of the nature of "real-world" sinusoids associated with rotating machinery

(b) Development of improved periodic time/frequency analysis tools for quasi-periodic processes.

(c) Implementation of theoretical statistics derived under previous funding in the development of a multi-resolution, intelligent methodology for estimating the spectral information associated with mixed random processes.

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SECTION B. TABLE OF CONTENTS

SECTION C

SUMMARY OF RESEARCH RESULTS

C1. BACKGROUND

This research is concerned with a class of random processes known as quasi-cyclostationary processes. Such processes can be found in a wide variety of disciplines, ranging from weather forecasting, to bio-rhythms, to rotating machinery. Our focus in this work was on rotating machinery operating at nominally constant speed. Under a previous AFOSR grant (F496209510090) we obtained a number of theoretical results pertaining to analysis of such processes using time-invariant and time-periodic spectral tools. Achievements included (i) characterization of the influence of period uncertainty on estimation of a periodic time/frequency spectrum associated with a nominally wide sense cyclostationary (wsc) process, (ii) large sample distribution descriptions for the AR(p) and MV(p) spectral estimators for processes with mixed spectrum, (iii) a time-to-angle transformation method to better accommodate period variability, combined with an improved method for tracking real sinusoids with slowly varying frequency, (iv) greater t into issues related to application of advanced spectral analysis methods for characterizing random processes associated with engines, compressors, and helicopter drive trains,(v) a *Matlab*-based virtual signal analyzer which incorporates a number of our results in a user-friendly fashion, and (vi) development of research collaborations and workshops which serve to bring signal processing problems associated with rotating machinery to a broader base of researchers in industry, defense and academic institutions. The objectives of the research associated with this final report were a direct extension of the above accomplishments. We now proceed to list each objective, and then discuss related achievements.

C2. THEORETICAL RESULTS

(a) *Characterization of the stochastic properties of "real" sinusoids.*

As opposed to a mathematical sinusoid, whose amplitude, frequency and phase are fixed for all time, a real sinusoid refers to the case where these items vary slowly over time. Such variations arise, for example, in the case of a machine which operates at an essentially constant speed. No machine, however, operates at an exactly constant speed. While the value of a Fourier series decomposition of a real sinusoid is clear, it could be argued that the viewpoint of a single, *real*, sinusoid can also be valuable. When this viewpoint was presented at [1]there was a uniform consensus among participants that it could provide much more physical insight into the phenomenon. The characterization of real sinusoids associated with rotating machinery has, under this grant, included vibration signals used to monitor the health of military helicopters. The properties discovered include (i) a fault condition may lead to changes in a real sinusoid not associated directly with the characteristic fault frequency, (ii) the statistics of this sinusoid are markedly different from those observed in the no-fault condition, and (iii) the stochastic structure of the real sinusoid time-varying parameters, namely amplitude and frequency, is well captured by an appropriate time series model which affords additional insight into the operation of the machine. More comprehensive results are included in [2].

Another valuable result of this research has been the identification of fundamental questions which could lead to an entirely new approach to signal analysis. For example, it is well known that the squared coherence function between to sinusoids of the same frequency should equal one, regardless of whether they arise from the same physical source. This has been a major stumbling block to effective coherence analysis for rotating machinery. It is equally well known that for sinusoids not at exactly the same frequency the squared coherence is zero. From a linear systems viewpoint these observations are obvious. But all too often one is tempted to ignore this viewpoint in favor of the incorrect interpretation that the sinusoids are either strongly related to each other (same frequency), or are essentially unrelated (different frequencies). The concept of real sinusoids permits one to assess how strongly related sinusoids at the same (or different) frequencies are related to one another, via the joint statistics in the time-varying amplitude and frequency information.

(b) *Completion of the development and statistical analysis of our time-to-angle transformation*
There are two issues which must be addressed in order to obtain valuable time/frequency information for real world quasi-periodic phenomena. One is accommodation of the randomness of the variable period. The second is decomposition of the deterministic and the random portions of the process. Under the previous AFOSR grant it was shown in [3] that without ongoing accommodation of the variable period the periodically time-varying spectral information will revert to time-invariant information. Furthermore, if a deterministic process such as a sinusoid is allowed to remain, because it is a time-invariant ridge in the time/frequency domain, its presence could camouflage valuable time-varying information. Both of these items can be addressed in the context of the estimation of the real sinusoid. We investigated two methods for this purpose: a constrained AR(2) model, and an extended Kalman filter (EKF). The AR model has a significant advantage over the EKF, in that it does not require knowledge of the state and observation covariance information. Its drawback is that one must specify the data window length over which is used to obtain a frequency estimate. Details of these results are included in [5] and [6]. The focus under the current grant was to be on the potentially ill-effects of band pass filter properties. Specifically, we conducted a preliminary study of filter properties in relation to tracking ability of both the AR and EKF methods. This was done using a large number of simulations, since the analytical approach was believed to be more effort than it was worth in the early stages of such an analysis. Our goal was to begin by simply gaining a better understanding of the general level of corruption such a filter might inflict. We found that so long as the real sinusoid's frequency remained within the filter bandwidth, and the local noise was relatively white, both methods performed similarly. The local SNR plays a clearly significant role. But we have not to date been able to identify a marked threshold behavior.

(c) *Evaluation of the influence of* (a) *and* (b) *on the MV(n) family convergence properties*

(d) *Development of a statistical hypothesis test for MV(n)-based detection of real sinusoids.*

(e) *Removal of real sinusoids for improved wsc spectrum estimation.*

Items (c), (d) and (e) have been addressed in the context of the following item, which we determined is more appropriately addressed prior to these items.

(d) *Development of a multi-resolution, intelligent methodology for estimating the spectral information associated with mixed random processes*

As a consequence of our results concerning the statistics associated with families of spectral estimators we are now developing an entirely new approach to spectral estimation for complex random processes. Traditionally, spectral estimation has been concerned with selection of a single "best" spectral model, using model order selection criteria. But this begs a basic question. If, for example, it is determined that an AR(p) model is best, then is such a model robust with respect to perturbations of the chosen model order, p? If it is not, then one should reasonably question the chosen model. Our new approach addresses this question directly. Specifically, we compute two different families of spectral: one associated with continuous spectrum, and the other with point spectrum. We then look at the statistics associated with the members, as well as functions of them, to determine in which frequency regions they are robust with respect to model order. In regions where they are not, we proceed to implement spectral decomposition tools as necessary, since mixed spectrum can be a major source of lack of robustness. The marginal statistics of these families were presented in [7] and [8], an expanded version of which is [9]. We are investigating a number of tone detection methodologies based on such families. One example is using the AR family [10].

Our current effort is being carried out in an integrated framework, in the sense that we are addressing the above issues in the context of multiresolution, multi-dynamic range spectral characterizations. This effort relies on the identification of spectral ranges where variability, based on, for example, [7] or [8], is acceptable, versus where it is not. If it is not, the most common reason is the presence of real tones, which are highly sensitive to varying spectral model orders. In this case we increase the frequency resolution in that range via heterodyning, and apply our tone separation tools. We take into account the increased variability of this procedure due to loss of data in the heterodyning process in our mixed spectrum variance

expressions. This process is repeated until either the variability is acceptable or the amount of data is insufficient to achieve the desired variability.

C3. CONCLUSIONS

In summary, we believe that there is a significant need for such advanced spectrum estimation methodologies. This was highlighted in our ONR/AFOSR-sponsored workshop on military helicopter condition monitoring [11]. We also feel that our integrated approach, in which various tools are developed not only in parallel, but in recognition of real world issues such as statistical variability of tones, is the appropriate mode for this research. It has led to improved characterizations of mixed spectral data, and has spawned new and potentially valuable research ares.

C4. BIBLIOGRAPHY

[1] Sherman, P. J. "On the statistical nature of real sinusoids associated with rotating machinery", The 2nd U.S./Australian DASP, LaSalle, IL, August 22-25, 1999.

[1] Lau, S. and Sherman, P. J. "Periodic spectral analysis for processes with slowly varying period" 1997 International Conference on Acoustics, Speech and Signal Processing, Seattle, WA, 12-15 May 1998.

[2] Sherman, P. J. "On the statistical nature of real sinusoids associated with rotating machinery", Signal Processing, (Elsevier Publ.), to appear.

[3] Sherman, P.J. and White, L.B. "Periodic analysis of diesel vibration data", *Jnl. of the Acoustical Society of America*, **96(8)**, 3285-3301, December 1995.

[4] Lau, S. and Sherman, P. J. "The influence of period variation on frequency and time/frequency analysis of the Westland helicopter data", 1998 IEEE Workshop on Statistical & Signal Array Processing.

[5] Sherman, P. J. "Signal processing issues concerning nominally periodic random processes with applications to rotating machinery", Signal Processing, (Elsevier Publ.), to appear.

[6] Lau, S. and Sherman, P. J. "Statistical analysis of constrained AR(2) frequency estimators", Journal of Time Series Analysis, (being revised)

[7] Liu, X. and Sherman, P. J. "Asymptotic statistical properties of the Capon MV spectral estimator for mixed spectrum processes", 1998 IEEE Workshop on Statistical & Signal Array Processing.

[8] Sherman, P.J. and Lau,, S.S. Asymptotic statistical properties of auto-regression in modeling processes with mixed spectrum", *Proc. of the 1998 International conference on Acoustics, Speech & signal processing*, Seattle, WA, 12-15 May 1998.

[9] Lau, S., Sherman, P.J. and White, L.B. "Asymptotic statistical properties of AR estimators for processes with mixed spectra", *IEEE Trans. on Information Theory.*, (in review)

[10] White, L. and Sherman, P. "Detection of tones in colored noise using a family of AR spectrum estimators", Conference on Information, Decision and Control, Adelaide, Australia, 8-10 Feb. 1999.

[11] Workshop on Signal Analysis Methods for Improved Condition Monitoring of Helicopter Drive Trains", 25-27 Feb, 1998, Virginia Beach, VA, Sponsored by the Office of Naval Research. Results appear in a special issue of *Mechanical Systems & Signal Processing*, **14(4)**, July 2000.

D. PUBLICATIONS

D1. Archival Journal Papers

d1.1.. Sherman, P. J. "Signal processing issues concerning nominally periodic random processes with applications to rotating machinery", *Signal Processing*, _ 2000

d1.2.. Sherman, P. "On the statistical nature of real sinusoids associated with rotating machinery", *Journal of Digital Signal Processing*. _2000

d1.3. Lau, S. S. and Sherman, P. J. "The influence of period variation on time-frequency analysis of the Westland helicopter data set", *Mechanical Systems & Signal Processing*, **14**(4), pp. 571-578.

d1.4. Lau, S. S. and Sherman, P. J. and White, L. B. "Asymptotic statistical properties of auto-regression in modeling processes with mixed spectrum", *IEEE Transactions on Information Theory.*(too appear 4/02)

d5. Wen, L., Wang, X. and Sherman, P. J. "Using variability related to families of spectral estimators for mixed random processes", *ASME Journal of Dynamic Systems, Measurements and Control*, **123**, 12/2001, pp. 572-584.

D2. Published Conference and Workshop Papers

d2.1 Sherman, P. J. and Lau, S. S. "Asymptotic statistical properties of auto-regression in modeling processes with mixed spectrum", *Proceedings of the 1998 International Conference on Acoustics, Speech and Signal Processing*, pp. 2289-2292, Seattle, WA, 12-15 May 1998.

d2.2 Lau, S. and Sherman, P. J. "The influence of period variation on time/frequency analysis of the Westland helicopter data", *Proceedings of the 9th IEEE SP Workshop on Statistical Signal & Array Processing*, 180-183, September 14-16, 1998, Portland, OR.

d2.3 Liu, X. and Sherman, P. J. "Asymptotic statistical properties of the Capon MV spectral estimator for mixed random processes", *Proceedings of the 9th IEEE SP Workshop on Statistical Signal & Array Processing*, 328-331, September 14-16, 1998, Portland, OR.

d2.4 White, L. B. and Sherman, P. J. "Detection of sinusoids in unknown colored noise using ratios of AR spectrum estimates", *Proceedings of the 1999 Conference on Information, Decision and Control*, February 8-10, 1999, Adelaide, Australia.

d2.5 Sherman, P. J."On the statistical nature of real sinusoids associated with rotating machinery", *Proceedings of the 1999 Defense Applications of Signal Processing*, 173-180, August 22-27, 1999, LaSalle, IL.

d2.6 Elling, M. and Sherman, P. J. "A Kalman filter based approach for estimating nonstationary VAR models via pole tracking", *Proceedings of the IEEE International Conference on Acoustics, Speech & Signal Processing*, 3864-3867, 5-9 June 2000, Istanbul, Turkey.

d2.7 Sherman, P. J. "On the statistical nature of real sinusoids associated with rotating machinery", *Proceedings of the IEEE International Conference on Acoustics, Speech & Signal Processing*, 4222-4225, 5-9 June 2000, Istanbul, Turkey.

D3. Conference and Workshop Papers in Review

d3.1 Sherman, P., Wen, L. and Wang, C, "Statistical properties of averages and other functions of spectral estimators for mixed random processes", submitted to *4th International Conference on Acoustical and Vibratory Surveillance Methods and Diagnostic Techniques*, Compiegne, France, October 16-18, 2001.

E. INVITED PRESENTATIONS

e1 Sherman, P. "Detection of periodic waveforms applied to machinery diagnosis and navigation signals", AFOSR Contractors' Meeting and Spring Technical Review, Minnowbrook conference Center, NY, April 14-16, 1999.

e2 Sherman, P. "Statistical Characterizations for Complex Stochastic Processes", Kharkov National Polytechnic University (Departments of Mathematics and Engineering). Kharkov, Ukraine, December 5, 2000.

e3 Sherman, P. "Intelligent, Multi-Resolution Statistical Characterization of Complex Stochastic Processes using Families of Spectral Estimates", Bogazici University (Departments of Mathematics and Engineering), Istanbul, Turkey, December 14, 2000.

e4 Sherman, P. Opportunities for Collaboration with Iowa State University for Pursuing a Graduate Degree in an Area Related to Statistical Dynamical Systems", presented to graduate students in mathematics-related fields at Kharkov National Polytechnic University, Kharkov, Ukraine, December 7, 2000.

F. INTERACTIONS / TRANSITIONS

F1. Interactions in Conferences, Workshops & Short Courses

f1.1. Organizer and chair of special session on rotating machinery at the next IEEE Workshop on Statistical Signal and Array Processing, Portland, OR in June 1998.

f1.2. Principal organizer of an ONR/AFOSR-sponsored workshop on helicopter diagnostics, Virginia Beach, VA, May 8-10, 1998.

f1.3. Technical program committee member for the 1999 Conference on Information, decision and Control, Adelaide, Australia, February 8-10, 1999.

f1.4. Organizer and chair of special session on DSP for industry at IEEE International Conference on Acoustics, Speech and Signal Processing, Istanbul, turkey, June 5-9, 2000.

f1.5. Presentor of 3-day vibration short course for industry, sponsored by SEM (Society for Experimental Mechanics): *"Seminar on Vibration Testing: Theory & Practice"* co-presented with Professor Kenneth McConnell 6 times over the period 1996-1999.

f1.6 Presentor of 2-day short course on *"Digital Signal Processing for Industrial Applications"* co-sponsored by Bogazici University (Istanbul, Turkey), Bruel & Kjaer (Denmark) and the Institute of Sound and Vibration Research (UK), June 9-10, 2000, Istanbul, Turkey.

f1.7. Organizer of Workshop on Applied Statistical Dynamical Systems, Kharkov National Polytechnic University, Kharkov, Ukraine, December 4-6, 2000.

F2. Transitions to Government and Industry

f2.1 Dissemination of algorithms to *Spectral Visualization & Development* (SVD), which is contracted with the Canadian D.O.D to incorporate results in military helicopter fleet . (c.f. Appendix 1).

f2.2 Dissemination of theory and algorithms to *Artesis*, a research branch of *Archelik*, which is one of the largest companies in Turkey.

f2.3 Dissemination of theory and algorithms to *Overland Conveyor*, to improve condition monitoring of conveyor belts used in mining operations.

G. NEW DISCOVERIES, INVENTIONS, PATENTS- none

H. INTERNATIONALIZATION EFFORTS

h1. In the process of laying the groundwork for an *International Institute for Applied Statistical Dynamical Systems* [see Appendix 2]

h2. Working with U.S. State Department and affiliate agencies (CRDF and STCU) to develop research collaborations with Ukraine and Turkey related to nonproliferation initiatives. Major contacts:

- *State Department*: Andrew Hood (hooda@t.state.gov) (formerly: Jennifer brush)
- CRDF (*Civilian Research & Development foundation*): Mathew Davies (mdavies@crdf.org)
- STCU (*Science & Technology Center for Ukraine*): Arthur DuCharme (Kiev) (ducharme@stcu.kiev.ua)

I. FUTURE PROPOSALS

The research supported by this grant has given rise to areas for continued research, expanded collaboration and opportunities for enhanced undergraduate and graduate education. The following proposals are currently being formulated for submission over the next 6 months:

- *"Development of a new technology for robust early detection of blade cracks with application to vibro-acoustic monitoring of critical rotating machinery systems"*, joint with professor Leonid Gelman of the ME Department at Kiev National Polytechnic University. Being submitted to STCU and NSF.

- *"Development of Advanced Mathematical Methods for Improved Diagnostics of Neurological Dysfunctions with Application to Chernobyl Effects in Ukraine"* joint with team from Kharkov National Technical University (Engineering and Mathematics) and Kharkov State Medical University. Being submitted to STCU and NIH. [See Appendix 3.]

- *"The Technology of Precision Machining and the Working Characteristics Control on Surface Layer with the Help of Random Process Theory"*, joint with team from Kharkov National Technical University (Engineering and Mathematics), FED (a major Ukraine manufacturing industry). Being submitted to STCU and NSF. [See Appendix 3].

- *"Program in Applied Statistical Dynamical Systems"* to be submitted to NSF IGERT program.

J. GRADUATE STUDENTS

j1. Wen, L. "Development of an intelligent, robust method for estimation of mixed stochastic processes", Ph.D. expected graduation date- 12/2002.

j2. Wang, C. "Development of Bayesian/Kalman filter models for decomposing mixed stochastic processes", Ph.D. expected graduation date- 12/2002.

APPENDIX 1

Canadian D.O.D. Group that is purchasing a data analyzer system from SVD which incorporates many results obtained under this and a previous AFOSR grant.

ATESS, Integrated health Monitoring Group
(In-house consulting and test group for Canadian AF)
CFB Trenton, P.O. Box 1000 STN Forces
Astra, ON K0K3W0

Individuals:

Captain Alain Robichaud (Group CO)
Sgt. Colin Ostergard
Mcpl. John Potter (in charge of Sea King & Labrador fleets)
Cpl. Gabe Kato
Mcpl. Tom Coolen

APPENDIX 2

Institute of Applied Statistical Dynamical Systems
Iowa State University
Ames, IA 50014

Draft 9/2000

Forward

In view of expanding globalization which is taking place, there is an increasing need for development of international collaborations in areas of education, research, business and government. One approach that ISU could take to effect such collaborations is proposed here. The ISU Department of Statistics is not only renowned for its size and quality, but also for its multidisciplinary faculty. It is proposed that this department, along with departments associated with various joint STAT faculty serve as the basis for an international institute. Specifically, this document is concerned with the establishment of an Institute of Statistical Dynamical Systems. This will be an international institute, including various departments and colleges at ISU, as well as partner institutions abroad. This document includes a general description of the institute that is envisioned. This is followed by a description of the first phase of the plan to realize this institute.

1. The Institute that is Envisioned

Overall Purpose

The overall purpose of this institute is to foster research, education and application of the theory of statistical dynamical systems in a framework of international collaboration of the highest quality. This collaboration shall include, but is not limited to, joint research programs, faculty and student exchanges, consortium programs with industry, graduate level courses offered by visiting academics at ISU and other partner institutions around the world, international workshops, and an advisory committee whose primary function is to identify new areas of applications related to international needs in areas of physical and social sciences, engineering, medicine, and other disciplines.

Statistical Dynamical Systems

A dynamical system is a relationship between user-defined "input" and "output" variables which are allowed to vary over, for example, time and/or space. A simple example might be an "output" which is EEG measured over time and at a number of spatial locations on a person's head. The "input" might be the person's heart rate and intake of a continuously administered drug. Another example involving EEG might be the desired for a model-based characterization of the EEG signal itself, to be used for detection of epileptic spikes. Here, there is no measured input. Instead, EEG, which is a stochastic process, is viewed as the "output" of a dynamical system whose "input" is a fictitious white noise process. Thus, included in our concept of a dynamical system are not only a relation between measured inputs and outputs, but also both deterministic and stochastic processes. A statistical dynamical system is a dynamical system, wherein the system parameters are allowed to be not only dependent on space and/or time, but they are also allowed to be random variables, or describable by statistical models.

Structure of the Institute

The institute shall include four major elements: research, education, outreach and targeting of current and future areas of both application and institute research teams, and funding sources. All of these elements shall be addressed in the international framework of the institute. The key ingredients of each of these elements are now summarized.

Research

Both basic and applied research programs shall be promoted within an international framework, which shall include ISU partners at universities and research institutes around the world. Visiting research positions shall play a key role. These positions shall include university faculty, researchers in institutes and industry, and graduate students.

Education

Both M.S. and Ph.D. programs will be offered. Core curricula related to these programs shall include components, each of which is housed at a particular partner institution. Thus, all students will be required to spend a sizeable amount of their course curriculum in countries other than the U.S. Students shall also be required to have at least 6 months (12 months) of cooperative experience in foreign /institutes, laboratories, or industries for completion of their M.S. (Ph.D.) degree.

Outreach

Institute outreach shall include outreach to all entities affiliated with the institute. Outreach shall include workshops related to both the theory and application of statistical dynamical systems. It shall also include training programs so that individuals can interact more productively in the institute international environment. Examples include intensive language programs, computer skills, and briefings on cultural, social, economic and political aspects of the countries of partner institutions prior to visiting the same.

2. Phase One Plan

The first step toward realization of such an institute must, at the very least, include the following elements:

1. Identify at least 2-3 foreign universities that are strong in areas related to statistical dynamical systems, and develop joint research, education, and outreach programs.

2. Identify key industries and application areas that will serve to foster the interest in and value of the proposed institute.

3. Secure support from various government and private sector institutions to permit exchange of faculty and students.

4. Gain approval from the LAS College to expand the joint degree program in STAT to allow the partner to be another university.

3. Progress Related to Phase One Plan

1. Identify at least 2-3 foreign universities that are strong in areas related to statistical

dynamical systems, and develop joint research, education, and outreach programs.

Professor Sherman will travel to Ukraine and Turkey 11 September through 4 October of this year to meet with researchers in academe and industry to discuss research, education and outreach collaborations within the context of the envisioned institute. To date, the universities that have agreed to meetings are:

- Ukraine National Technical University (Kiev)
- Kharkov Polytechnic University (Kharkov)
- Bogazici University (Istanbul)

The Ukraine is an expedient starting point to establish collaborations for a number of reasons. First, academicians in this area have been traditionally very strong in the area of statistical dynamical systems. Second, the are special funding opportunities aimed at nonproliferation of scientists in that region who have been associated with weapons of mass destruction. Third, ISU has a well-established program involving Kharkov Polytechnic University for retraining mid-career women scientists to function effectively in market-based economies. The value of such a program, expanded to all scientists cannot be stressed enough. It is essential that not only language, but also cultural, political, economic, and societal differences between the partners of the envisioned institute be accommodated in order to develop effective collaborations.

Bogazici University in Istanbul, Turkey was also selected for a number of reasons. First, it is not only among the best universities in Turkey, but all classes are taught in English. Second, they have a very strong engineering school in application areas related to the thrust of the envisioned institute. In particular, approximately 18 of the 24 faculty in Electrical Engineering conduct research on topics associated with this area. Third, it is in reasonably close proximity to Kiev, so that travel and time expense associated with establishing a base for the envisioned institute is reduced. Fourth, while not a member of the European Union (EU), it is one of the listed partner countries that EU funding opportunities apply to.

Professor Sherman has arranged to present two seminars at the National Technical University. One will concern his current research in the area of statistical dynamical systems. The second will address the envisioned institute, with the intent of not only informing faculty and students, but moreso, to stimulate sufficient interest that during his stay funding proposals for exchange of faculty and students can be drafted. Specifics of the types of possible proposals are addressed in the next section of this document. Professor Sherman has also sent emails to academic researchers in both Kiev and Kharkov who have been supported by the *Science and Technology Center in Ukraine* (STCU) to carry out research in areas related to the envisioned institute. The hope is that these individuals will be willing to meet to discuss possible collaborations within the context of the envisioned institute. A summary of selected research programs supported by the STCU is provided in Appendix A. They give an idea of the areas of research that the STCU has supported in the past. The envisioned institute could serve to provide a common base for such currently disjoint efforts, resulting in value-added by combining resources and ideas.

Professor Sherman has been in communication with various department heads at Bogazici University (EE, ME, IE, MATH) to arrange meetings and seminars. The university will provide housing and will advertise these activities to both faculty and students, prior to his arrival. He has also submitted a proposal to offer 1-2 of a total of four possible courses in the area of statistical dynamical systems during the summer 2001 class session. This proposal is currently under consideration. It is conceivable that this 2-month activity will be expanded to mentoring 10-15

ISU undergraduate students, through an NSF REU grant that is being formulated by the ISU department of Material Science.

University individuals who, to date, have been assisting Dr. Sherman in setting up meetings and seminars include:

- Dr. Leonid Gelman, *National Technical University* (Kiev)
- Dr. Kaynak Okyay, *Bogazici University* (Istanbul)

Dr. Judith Maney, who will meet Dr. Sherman in Kharkov, is pursuing contacts for Dr. Sherman at Kharkov Polytechnic University

2. Identify key industries, institutes and application areas that will serve to foster the interest in and value of the proposed institute.

A significant portion of Dr. Sherman's trip will be devoted to this item.

Industries being contacted:

TurboAtom, Kharkov
Kharkov Aricraft Industries, Kharkov
Turk Elektrik Endustrisi, Istanbul

Institutes being contacted (will be invited to Dr. Sherman's seminars):
Kiev:
- Institute of Radio Physics and Electronics
- Institute of Fundamental Problems for High Technology
- Institute of Geophysics
- Institute of Physics and Technology
- Institute of Hydromechanics
- Institute of Mechanics

Kharkov:
- Institute for Single Crystals
- Institute of Radio Astronomy
- Institute of Physics and Technology

3. Secure support from various government and private sector institutions to permit exchange of faculty and students.

APPENDIX 3 Protocol of Visit (12/2000) to Ukraine

PROTOCOL OF VISIT

of Professor Peter Sherman, Iowa State University, USA, to National Technical University "Kharkov Polytechnical Institute", Ukraine

During Prof. Sherman's visit from December 5, 2000 to December 7, 2000 the following work was done:

1. The workshop with scientists from NTU "KPI" was held on December 5, 2000. Major scientists from research institute "Monocrystal" and technical representatives from FED also took part in the workshop. The following people spoke with reports:

   Prof. Bragina L.L. "The development of glass-composite coatings, glassy lubrications for the protection of metals and alloys under thermal machining and hot deformation"; Prof. Bayrachniy B.I. "Electrochemical methods of metal machining"; Prof. Gladkiy P.M. "Hydro-drive"; Prof. Verezub N.V., Prof. Dobrotvorskiy S.S., Prof. Mazmanishvili A.S. "The technology of precision machining". The discussion of the projects also took place.
2. The discussion was continued on December 6, 2000. As a result of the discussion, an integral project was created by Prof. Verezub N.V., Prof. Dobrotvorskiy S.S., Prof. Mazmanishvili A.S. called "The technology of precision machining and the working characteristics control on surface layer with the help of random processes theory".

   Then the project "The study of Chernobyl consequences influence on health condition of children and adult population of Ukraine" was discussed. The head of the department of nerve diseases Prof. Dubenko E.G., Prof. Grigorova I.A. from the department of nerve diseases, Docent Tovazhnyanskaya E.L. from the department of neurology took part in the discussion. The representatives of Institute of children's health also participated.
3. On December 7, 2000 Prof. P.Sherman delivered a talk at the workshop with students from NTU "KPI" on opportunities for graduate study at ISU and on participation of graduates in joint scientific projects.

The team for the steering group was chosen, with its task being making projects of joint scientific research work for funding from various International funding agencies, and also the plan of expected activities and co-operation in the nearest future was worked out.

The deputy vice-rector
on scientific and research
work of NTU "KPI"

Prof. G.V.Lisachuk

Professor of Iowa State University

Prof. P.Sherman.

ПРОТОКОЛ ВИЗИТА

Профессора государственного университета штата Айова, США, Питера Шермана в Национальный технический университет «Харьковский политехнический институт», Украина

Во время визита проф. Шермана с 5.12.2000 по 7.12.2000 была проведена следующая работа:

1. 5.12.2000 была проведена конференция с учеными НТУ «ХПИ», в которой приняли участие ведущие ученые научно-исследовательского института «Монокристаллов» и технические руководители производственного объединения «ФЭД». С докладами выступили: проф. Брагина Л.Л. «Разработка стеклокомпозиционных покрытий, стеклосмазок для защиты металов и сплавов при термообработке и горячей деформации»; проф. Байрачный Б.И. «Электрохимические методы обработки металлов»; проф. Гладкий П.М. «Гидропривод»; проф. Верезуб Н.В., проф. Добротворский С.С., проф. Мазманишвили А.С. «Технология прецизионной обработки изделий». Состоялось обсуждение проектов.
2. 6.12.2000г. продолжение обсуждения проектов. В результате обсуждения был выделен объединенный проект авторов проф. Верезуб Н.В., проф. Добротворского С.С. и проф. Мазманишвили А.С. «Технология прецизионной обработки изделий и контроль эксплуатационных характеристик поверхностного слоя с помощью теории случайных процессов». Обсуждался проект на тему «Изучение влияния последствий аварии на Чернобыльской АЭС на состояние здоровья детей и взрослого населения Украины». В обсуждении проекта приняли участие председатель Харьковского научного медицинского общества неврологов, зав. кафедрой нервных болезней Харьковского медицинского института проф. Дубенко Е.Г., д.м.н., проф. кафедры нервных заболеваний Григорова И.А., к.м.н., доцент кафедры неврологии Харьковского медицинского института Товажнянская Е.Л., а также представители института здоровья детей и подростков.
3. 7.12.2000 г. проф. Шерман П. Провел конференцию со студентами НТУ «ХПИ» по вопросам участия в научных проектах, совместных исследованиях и обучению в государственном университете штата Айова. Определен состав рабочей группы по составлению проектов по совместным научным исследованиям для участия в конкурсах на получение грантов различных международных фондов и написан план мероприятий по дальнейшей совместной работе.

Зам.проректора по
научной работе НТУ «ХПИ»

Проф. Г.В.Лисачук

Профессор государственного
университета штата Айова

Проф. П.Шерман